PIC WATER DESCALER

MARK STUART

Treat your water to the low-cost power of a microcontroller to reduce the level of scale build-up around your home.

A NUMBER of commercial Pipe Descalers are presently available. The simplest type consists of a small magnet which is strapped around the pipe, whilst others are more intricate and usually involve wrapping one or more coils of wire around the pipe and connecting them to a control box that delivers a fixed or variable frequency output voltage and current.

These devices are claimed to prevent new scale forming and gradually to encourage existing scale to dissolve back into the water and be flushed from the system. The exact chemical mechanism is not clear, but it seems that subjecting the water to a fixed or variable magnetic field alters the way in which the dissolved salts crystallise.

PIC Water Descaler in action.

The result is that a softer "scale" is formed which does not adhere to the pipes effectively. This softer scale is also claimed to require less soap and detergent, producing a lather more easily.

An experimental circuit (*Experimental Electronic Pipe Descaler*) was published in *EPE* in August 1993. This was a variable frequency unit with a low current output between 1400Hz and 2000Hz, and proved to be very popular. This new PIC based design adds a number of improvements and should be more effective.

DESIGN

It was decided that this design should be able to deliver a relatively high current to a coil wrapped around an incoming water pipe. Often such pipes are not readily accessible and so a compromise was necessary to have sufficient turns to be effective, without being too difficult to wind.

A single layer coil of 55 turns of 1/0·6 wire was chosen for a 15mm copper pipe. This will be the standard for most houses. Other dimensions of pipe can be accommodated by varying the number of turns to use a similar length of wire.

To ensure that the ideal frequency would be present for at least some of the time, a swept frequency drive was used, with the frequency continuously cycling from 1200Hz up to 14kHz and back. This range is convenient as it allows standard audio techniques to be used.

To keep construction simple the component count was kept low by using i.c.s throughout, and a separate double-insulated "plug-in" power supply to ensure electrical safety. To allow the circuit to be checked, a monitor l.e.d. was incorporated, along with an audible indicator that allows the actual current through the coil to be verified.

CIRCUIT DESCRIPTION

The full circuit diagram for the PIC Water Descaler is shown in Fig.1, together with the pinout information (Fig.2) for the PIC12C508 microcontroller IC2.

The incoming supply voltage passes via diode D2, which protects against reverse polarity, to the input terminal of the 1A voltage regulator IC4 where it is reduced to 5V. This simple arrangement protects the circuit components and allows a wide range of *unregulated* power supplies to be accommodated.

The ideal supply provides 8V at 250mA. Higher voltages can be used but will increase the temperature of IC4 accordingly. A small heatsink is recommended for voltages of 10V or more.

If a regulated supply is available, then a direct 5V connection can be made to the circuit, and IC4 removed – note though that there will not be any reverse polarity protection in this case.

Capacitor C5 ensures the stability of IC4 if the power supply lead is a long one, and C4 decouples the 5V supply. Additional decoupling is provided for IC2 by resistor R2 and capacitor C1.

The a.c. descaling signal is generated by IC2 which is a pre-programmed PIC12C508 microcontroller chip. The program code generates a variable frequency output signal sweeping up and down between 1200Hz and 14kHz.

A pre-programmed chip for this project is available from Magenta so that the project can be built without any programming knowledge. The use of microcontrollers is becoming commonplace – even in simple projects such as this. A look at the circuit published in 1993 shows that eight components are used to generate the descaling signal where the present circuit uses just three and provides a more complicated output. The circuit also uses less board area and requires less assembly work.

The output from IC2 is a square wave swinging from 0V to 5V. This is reduced in amplitude by the potential divider action of resistors R3 and R4 to a more suitable level to drive IC3. Capacitor C2 removes the d.c. component of the signal and C3 reduces the high frequency component and rounds the edges of the square wave.

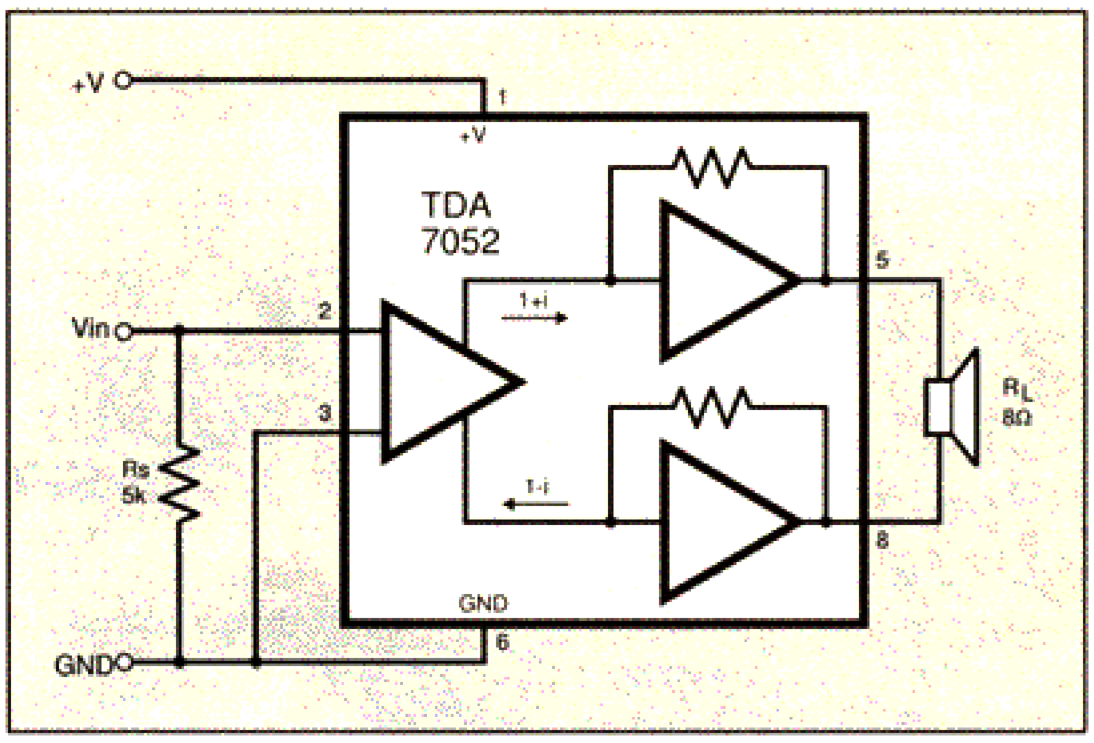


Fig.3. Internal structure of the TDA7052 audio power amp.

POWER OUTPUT

An audio amplifier with a "full bridge" output is formed around IC3. The internal circuit, which consists of two amplifiers driven in antiphase is shown in Fig. 3.

The output from IC2 has been programmed to have a short pause after each frequency sweep, so that the l.e.d. will appear to flicker. As the pauses are very

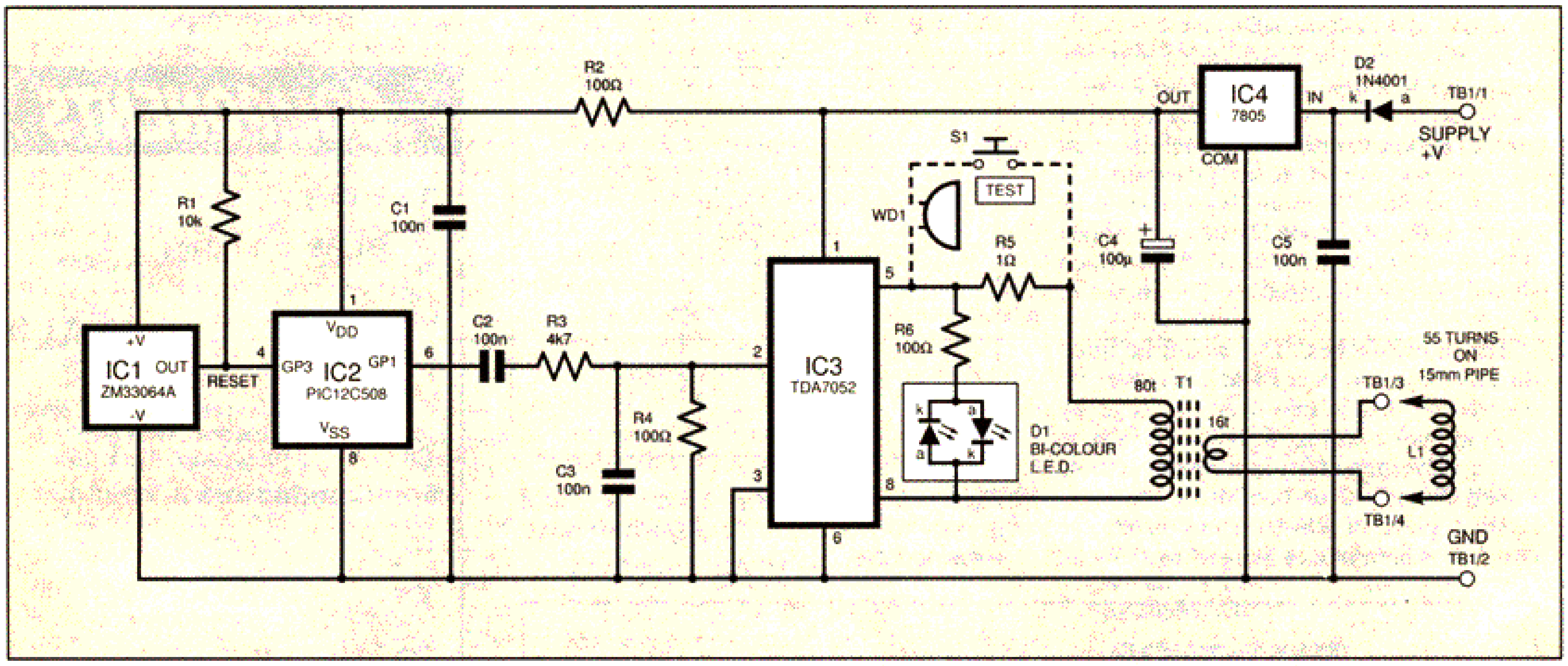


Fig.1. Complete circuit diagram for the PIC Water Descaler. The power supply for the circuit is taken from an unregulated plug-in "mains adaptor". The ideal supply provides 8V at 250mA. Components shown "dashed" are optional for testing.

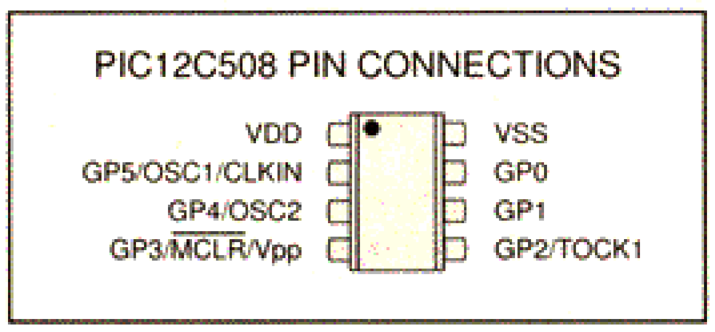


Fig.2. Pinout details for the PIC12C508 microcontroller.

RESET

A small 3-pin device, IC1, monitors the supply voltage and holds the microcontroller "reset" pin low until the supply exceeds 4·6V. This ensures that IC2 starts and runs its program correctly and is shut down if the supply voltage falls for any reason.

This component can be left out provided the supply voltage is always switched on "cleanly". In practice, there may be occasional surges in the supply voltage which could "crash" the program. This would not be a problem in some applications, but in an unattended circuit such as this it is possible that a crash could go unnoticed for weeks, during which time the circuit would be ineffective.

This device has been chosen because it is happy working at low supply voltages, and because it can deliver a substantial output current. It also has internal over temperature and short circuit protection.

The coil around the pipe has a very low resistance – less than 0·5 ohms. In the earlier design, the current was limited to a few milliamps by a series resistor, and no attempt was made to optimise the coupling. In this design it was decided that plenty of current would be provided to have as much effect on the water as possible.

A coil matching transformer T1 has a turns ratio of 5:1 and raises the impedance of the coil by the square of the turns ratio, so that the output of IC3 sees an impedance of 12 ohms. This is a very effective matching method, and results in a current of 1A flowing in the coil.

MONITORING

The output voltage from IC3 drives a red/green bi-colour l.e.d. D1 via current limiting resistor R6. This should glow *orange* when a square wave output is being delivered. If a *fault* occurs in IC3 it may glow red, or green.

short, this will appear only as a very brief "glitch" but will give an indication that the program is running correctly.

A second monitoring option is provided by a piezo sounder connected across resistor R5. This will reproduce the audio frequency output provided there is sufficient current flowing through R5 to drop an appreciable voltage.

If the water pipe coil L1 is disconnected for any reason, the output load will have been removed and the output current will fall so that the residual voltage drop across R5 is very small and the resulting output practically inaudible. With the coil connected, current flow increases the voltage across R5 resulting in a clearly audible output.

A small push-to-make switch (S1) can be fitted if audible monitoring is to be used frequently. In practice the coil is unlikely to become disconnected, and so this feature may be left out, or just used for setting up.

The current consumption of the circuit is approximately 250mA when running normally. If the coil is disconnected this falls to 25mA or so depending upon the frequency.

CONSTRUCTION

The PIC Water Descaler circuit is built on a small printed circuit board (p.c.b.) which slides into p.c.b. guide slots in the recommended case. This board is available from the *EPE PCB Service*, code 170.

Before fitting any components check that the board fits correctly into the case, and if necessary file the ends slightly. The incoming power supply and outgoing water pipe coil connections are made to a 4-way p.c.b. mounted terminal block TB1. A small notch should be cut in the edge of the case so that the wires can pass freely.

A full size underside copper track master pattern, together with the topside component layout, is shown in Fig. 4. A d.i.l. socket should be used for IC2, but *not* for IC3 which relies on heatsinking via its pins to the copper track area on the p.c.b.

Voltage regulator IC4 stands up on the board, and can be fitted with a small heatsink if a higher power supply voltage is to be used. A small strip of aluminium 15mm × 40mm or so will be adequate.

Fit the resistors, capacitors, and the socket for IC2 first, taking care to identify the negative lead on capacitor C4 and to fit the i.c. socket with its pin 1 identification the right way round. Reset generator IC1 should be fitted with its body profile as shown in Fig. 4. Diode D1 has its cathode (k) end identified by a silver band which should be fitted to match the line shown in Fig. 4.

The bi-colour l.e.d. D1 should be fitted directly onto the board and bent over 90 degrees so that it lies over the edge by 5mm as shown in Fig. 5. It should then fit into a corresponding 3mm diameter hole drilled in the lid or bottom of the case. A small piece of Blu-tak stuck inside the case lid or bottom can be used to show an impression of the l.e.d. and so indicate the drilling position when the board is slid into the case p.c.b. guides.

As D1 is a bipolar l.e.d. it can be fitted either way round. It is driven by a.c. and so will light red in one direction and green in the other giving a sort of yellow/orange appearance. It really doesn't matter which polarity gives red and which green.

OUTPUT TRANSFORMER

Ferrite pot-core transformer T1 must be correct for this circuit to operate correctly. It is made up from a coil former, winding wire, two ferrite cores/cups, and a pair of spring clips that hold the completed assembly together.

The 80-turn primary is wound first. Winding is much easier if a suitable spindle – such as a pen or pencil – can be found, over which the former can be held.

Use 28s.w.g. enamelled wire and wind in neat layers as far as possible. There is no need to insulate between layers, but it can make the winding very neat if each layer is finished with thin insulating tape before winding the next one. When 80 turns have been wound finish the winding in the same slot as the start, and twist the two ends loosely together.

The secondary winding is 16 turns of the same wire wound over the primary winding starting and finishing in the opposite slot from the primary. The turns ratio is not critical so don't unwind the primary if you can't remember whether there are 79 or 80 turns!

When the windings are complete, bend over the ends of the secondary so that you can tell them from the primary, and fit the two core halves into the former. Align the core halves and carefully press the spring clips into position to hold the whole assembly together.

Cut the winding ends down to 30mm from the core and strip the insulation from the end 10mm. The enamel can be stripped with heat from a soldering iron, but it is helpful if some enamel can be removed first by drawing the wire between a folded piece of fine abrasive paper.

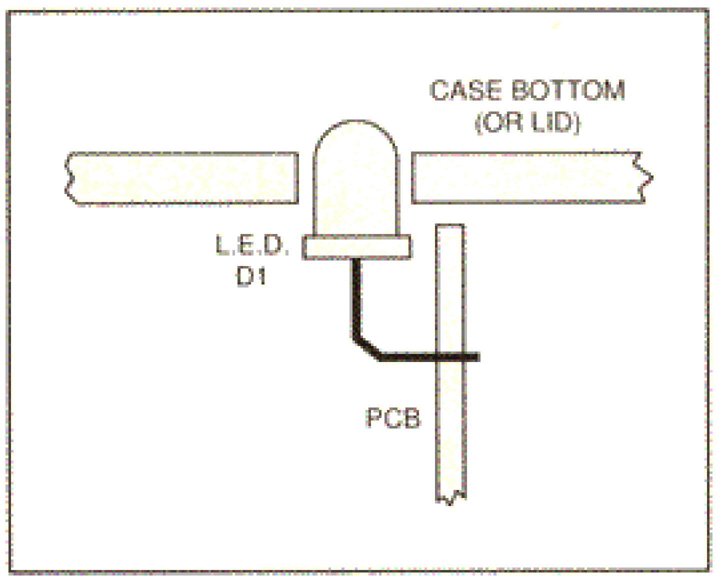


Fig.5. Mounting the l.e.d. at right angles to the p.c.b. to align with case viewing hole.

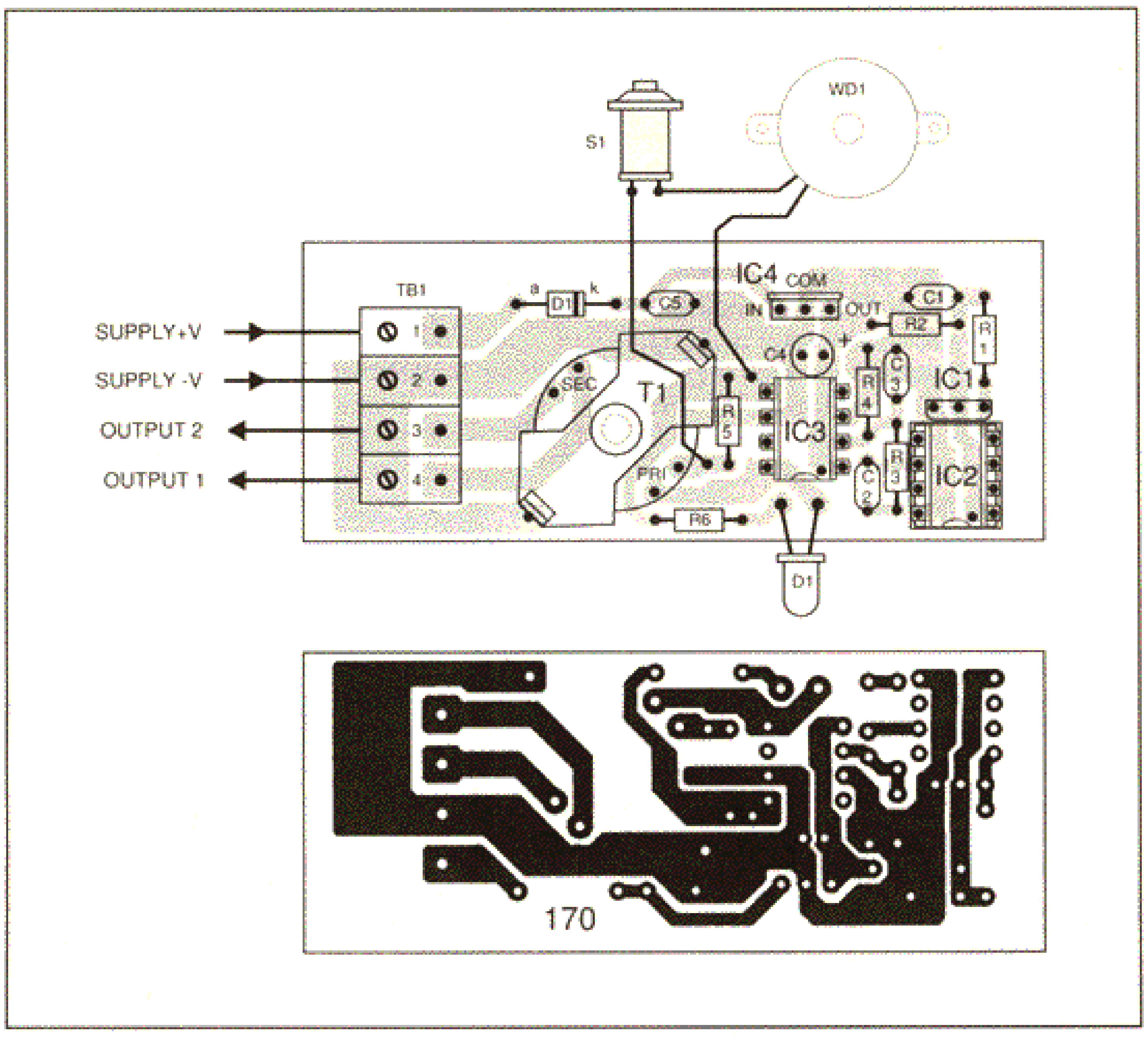


Fig.4. Printed circuit board component layout and full size copper foil master for the PIC Water Descaler. The piezo sounder and pushbutton switch are optional components.

COMPONENTS

See SHOP TALK Page

Resistors

R1	10k
R2, R4, R6	100Ω (3 off)
R3	4k7
R5	1Ω

All 0·25W 5% carbon film

Capacitor

C1, C2, C3, C5	100n polyester 63V, 5mm lead spacing (4 off)
C4	100µ radial elect. 10V

Semiconductors

D1	3mm bi-colour l.e.d.
D2	1N4001 50V 1A rect. diode
IC1	ZM33064A 4·6V reset generator
IC2	PIC12C508 pre-programmed microcontroller (see text)
IC3	TDA7052 audio power driver
IC4	7805 5V voltage reg.

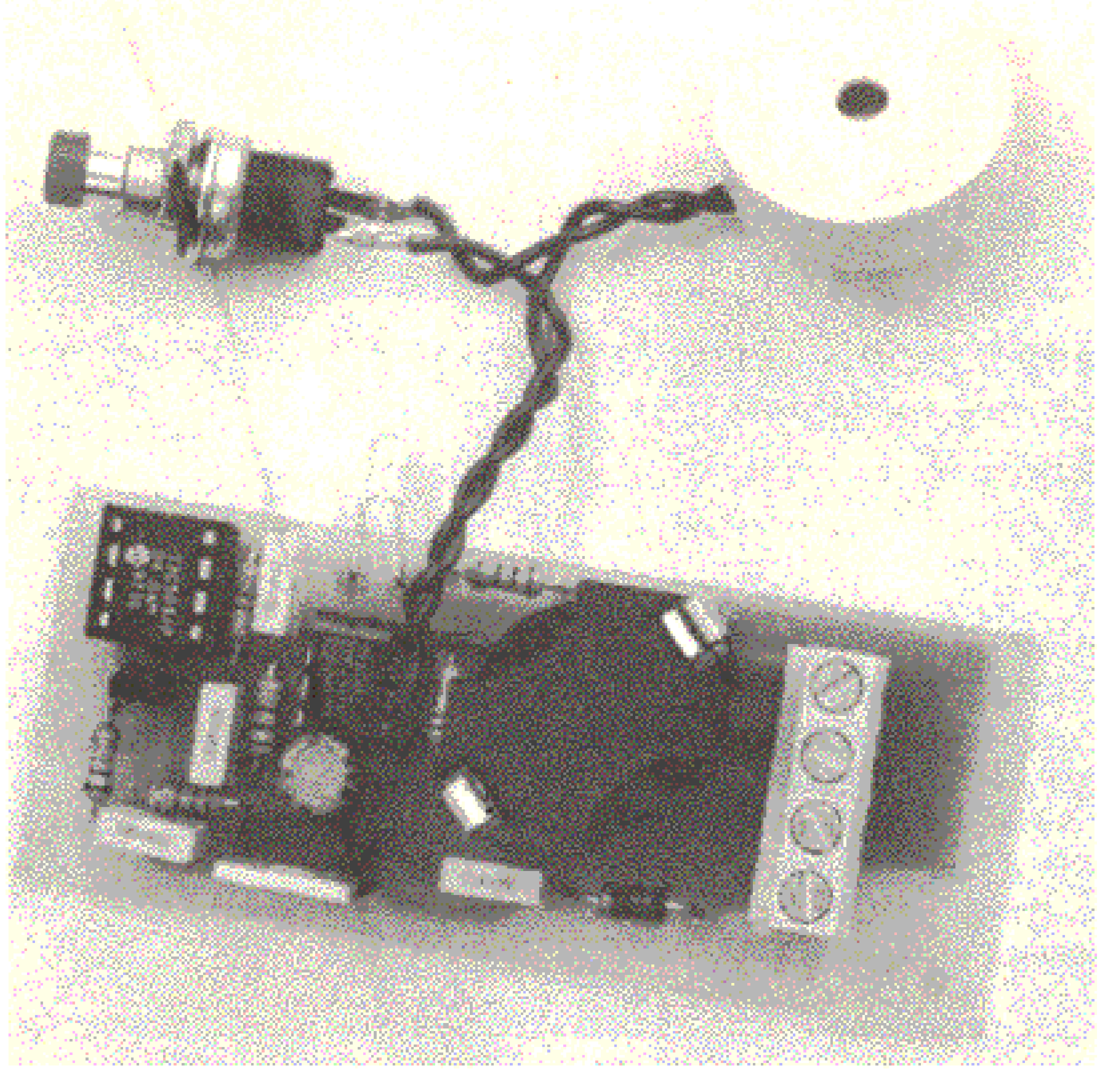
Miscellaneous

T1	ferrite pot-core output transformer: bobbin – 4322 021 38461 and clip – 4313 021 03960 (Philips). Core N41 (Siemens) – see *Shoptalk*
WD1	piezoelectric sounder (optional)
S1	pushbutton switch, push-to-make (optional)
TB1	4-way, p.c.b. mounting, connecting block

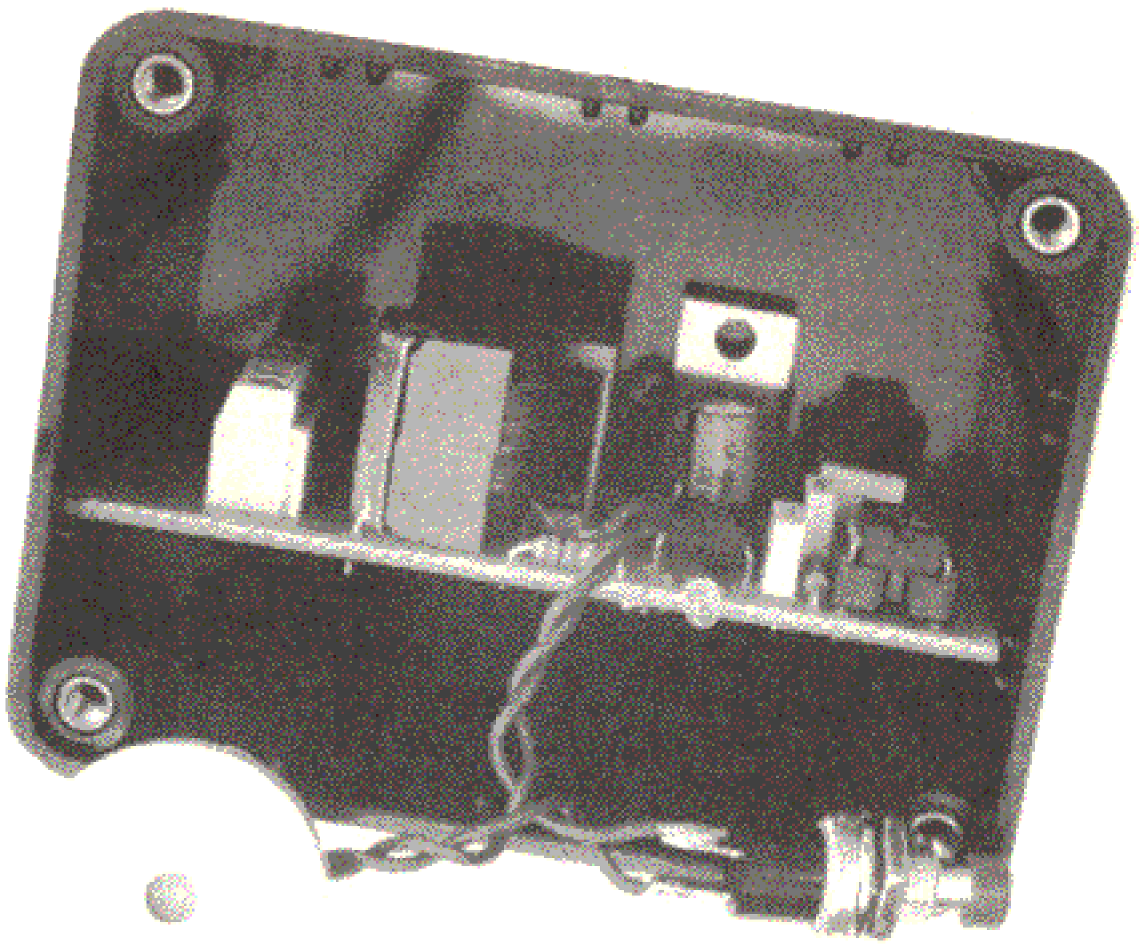
Printed circuit board available from *EPE PCB Service*, code 170; plastic case, size 80mm x 60mm x 40mm approx.; 8-pin d.i.l. socket; 28s.w.g. enamelled copper wire for output transformer (see text); length of 1/0·6 standard insulated wire for water pipe coil (see text); solder etc.

Plug-in unregulated power supply (mains adaptor) – see text.

Approx Cost Guidance Only £25 excluding plug-in PSU



Completed circuit board showing positioning of components. Note the l.e.d. leads have been bent 90 degrees to the p.c.b.



Finished printed circuit board slotted into the small plastic case. The test switch and piezo sounder can be sited remotely from the case.

The transformer is fixed to the board by the two pins on the spring clips. Make sure it is the right way round, so that the primary and secondary windings are in the correct positions to be threaded through their connecting holes on the board.

Thread through the wires, leaving 10mm of free wire above the board and then solder the tinned ends to the connecting pads. The polarity of each winding is not important – just make sure that the primary and secondary have not been mixed up.

The use of a piezo transducer for monitoring is optional. Simply connect any suitable transducer in series with a push-to-make switch across the two p.c.b. connecting points provided. The transducer and switch can be mounted in or on the Descaler case, or remotely in a more convenient place.

TESTING

The circuit is relatively simple, has only has one function, and so should be easy to test. Before testing, inspect the board carefully for dry joints, solder bridges, and incorrectly placed or polarised components.

Beware! Some types of solder have conductive flux residues which must be cleaned off – this seems to be more of a problem lately as solder manufacturers have sought to eliminate certain chemicals from their fluxes and have added others!

Standard rosin flux Multicore solders are generally OK, and their residues can be left in place without any difficulty. If in doubt, check the type of solder, and clean the copper side of the board with washing-up liquid and water, and make sure that the board is thoroughly dry before continuing.

The Descaler should first be checked without connecting a water pipe coil, and without inserting IC2. Begin by applying a power source and check for 5V on the output of IC4. Any supply from 8V upwards should give the correct output.

An input of less than 8V will give a lower voltage output as the regulator will not function correctly. A benefit of using this type of voltage regulator is that it incorporates over-temperature and short-circuit protection.

Next, check the output pins (5 and 8) of IC3. These should both sit at half of the supply voltage, and so there will be zero volts across the primary of T1 and l.e.d. D1 will be off. Pin 2 of IC3 will be held at 0V via resistor R4.

As the supply voltage is correct, the output of the "reset" device IC1 should be turned off and so the voltage at pin 4 of the socket for IC2 should be pulled up to 5V via resistor R1. The circuit current at this stage should be between 5mA and 15mA.

PIPED SOUNDS

If all is well so far, switch off, allow a few seconds for capacitor C4 to discharge, and plug in programmed microcontroller IC2. Switch on and check that the supply voltage is still correct and that the l.e.d. is now on.

An audio check can be made by connecting the piezo transducer across the two output terminals TB1/3 and TB1/4. The circuit should be producing a rising and falling high pitched tone. Note that as the microcontroller generates the different pitches by altering numbers in counting registers, the pitch will be varying in small increments and will sound "notchy".

If there isn't an output, check that pin 4 of IC2 is being pulled up correctly, and that IC1 is the right way round. Resistor R2 in the supply line will protect IC1 and IC2 from damage if they have been fitted incorrectly.

Once everything is running, check the supply current which should be between 10mA and 20mA. A high current reading will result if transformer T1 has been fitted with its primary and secondary windings interchanged.

The water pipe coil L1 should now be wound around the pipe. Take care, and remember to leave enough spare wire to connect to the Descaler p.c.b. Circuit matching has been optimised for 55 turns of 1/0·6 standard insulated connecting wire wrapped in a single layer around a 15mm copper pipe with 300mm flying leads.

If the Descaler cannot be mounted close to the pipe, it is possible to extend the leads, but the current flow will be reduced. Using thicker extension leads will help, but it is better by far to mount the unit close to the pipe, and extend the power supply cable – up to five metres or so should be possible without any reduction in performance.

When the water pipe coil is connected to the Descaler the supply current will rise to around 250mA and IC3 will become slightly warm. The optional piezo sounder, connected across resistor R5, should produce a low level audible output, which will stop if the coil becomes disconnected.

SOFTWARE SOURCING

This project uses the 12C508 PIC, a fairly new addition to the Microchip range, and has been pre-programmed by Magenta Electronics so that the Descaler can be built by anyone without prior knowledge of programming. See *Shoptalk* for details.

Readers who wish to program their own PICs can acquire the software either on a 3·5 inch disk from the *EPE* editorial office or download it from our Web site (there is a nominal charge for the former, but the latter is Free – again see *Shoptalk* page). The Web site file is in the sub-directory **/PICdescaler.**

USE

Once completed and installed, the PIC Water Descaler should be switched on, checked, and left to get on with the job. The gradual descaling and prevention of new scale formation should begin immediately.

Note that the Descaler is supposed to work not by altering the amount of lime in the water, but by modifying its properties. The only way to see if it is effective is by observing the formation (or hopefully, lack of formation) of scale over a period of time.

We look forward to hearing of the results achieved by constructors of this project.